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Integrated Pest Management Decision Support System (IPM-DSS) a tool to support management of tree diseases in Kenya

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Abstract

Tree diseases have been noted as one of the major causes of abnormalities and malformations on perennial plants. Tree disease research in Kenya has resulted in a list of diseases identified to cause significant losses on forest plantations. The need for management of such diseases have been on the increase. The Decision Support System (DSS) was envisioned to help stakeholders make decisions to manage tree diseases on farm and in tree plantations. Information was collected across Kenya on diseases affecting seed, seedlings, plantations, natural forests and post-harvest products in sawmills. The data was entered into excel sheets and organized for database administration on MySQL software. Over 20 major fungal species were identified and their biology, distribution and management determined. This information was further fed into a query system to allow different groups of stakeholders to access the information for diagnosis and control of tree diseases. Results showed that major tree diseases in Kenya were caused by fungi belonging to the families; Botryosphaeriaceae, Nectriaceae, and Amphisphaeriaceae. The data and information availed through this query system is being used in trend analysis for proactive control and management of tree diseases in Kenya. It will also be used for farmer advisory services through closest match selection of symptom appearance based on the tree species. The query system is an innovation that will also be used for Citizen Science Data Capture to aid Kenya Forestry Research Institute in detecting emerging diseases in real-time for phytosanitary measures. The identification of commonly occurring pathogens in commercial forestry species in the country has led to research towards their control and tree improvement for resistance to tree diseases. Future plantation establishment should be based on resistant species and high-quality germplasm for maximum survival and improved yields.

Key words: Advisory services, Botryosphaeriaceae, citizen science, Decision Support System, Integrated Pest Management, tree diseases.

Introduction

The first disease identified in the Kenya Forestry Research Institute (KEFRI) pathology section was a seedling disease on *Pinus pinea* in 1953 (Njuguna & Machua, 2021). The pathogen responsible was identified as *Fusarium* fungal species. Incidences of introduced species of pest and disease outbreaks have been on the increase over time. Among the diseases, *Botryosphaeria* canker is prevalent on Eucalyptus trees. The other notable diseases include *Dothistroma* needle blight (*Mycosphaerella spp.*) and *Diplodia pinea* (*Sphaeropsis sapinea*) on pines, cypress canker (*Lepteutypa cupressi*), armillaria root rot (*Armillaria mellea*). Common disease symptoms recorded in Kenya include; stem canker that appears as a sunken area with discoloration on a tree stem or twig, damping off (death of seedlings on the nursery bed before or after germination), twig and branch dieback (death of shoots from the leader progressing toward the stem). Other symptoms recorded on foliage include; leaf blight (brown turning of foliage from green to yellow and finally to brown indicating death of the leaves or needles), leaf rust (brown appears on the leaf margin causing the leaf to curl and die) (Agrios, 2005).

These pathogens have global distribution with many being exotic having used different pathways to infect both exotic and native tree species (Slippers *et al.*, 2007). The different pathogens are spread through wind, water and root to root contact (Njuguna *et al.*, 2011). Control measures include proper sanitation, use of fungicides, removal of infected plant parts, surface sterilization and use of clean certified seed when sowing (Njuguna & Machua, 2021). For post-harvest diseases, wood can be treated with preservatives to prevent infection by various stain fungi commonly recorded on timber.

A Decision Support System (DSS) is an information-based system used to help in determining best course of action and their best sequence. It is built upon a model management system, user interface and knowledge base. It is an interactive tool combining software, human interaction, models and hardware

(Tripathi, 2011). It supports the user's decision-making process as an extra help in the management of tree diseases and pests. The model management system which stores the model developedto help in decision making e.g. presence of insect will direct you to insect pest data. It also requires a user interface which is the homepage where a user keys in the ideas for processing to get possible solutions. KEFRI holds data that spans from 1950s to 2020 on pests and diseases in Kenya. The software makes suggestions based on data contained in the knowledge base which is the data uploaded onto the software application. It may include information from internal and external sources which can be in the form of backend data or publications. Decision Support Systems are a machine learning tool and form compendia for access to information. The system brings together human judgement and computer-based solutions for solution finders to choose a course of action, which in this case is management of tree diseases.

This is the basis upon which the KEFRI Integrated Pest Management (IPM) DSS was envisioned. The tool will be an interactive web-based application for management of tree pests and diseases and will offer advisory services to tree growers on timings of the control and management of tree diseases across different agro-ecological zones in the country. The application is expected to provide stakeholders with valuable information on best methodologies for prediction, diagnosis and management of forest pests and diseases.

Methodology

Information used in this study was collated from records in the forest pathology laboratory, postgraduate research studies as well as advisory service visits to stakeholders within the country. Other records used came from forest plantations and tree nurseries in the region. The pathology team responds to foresters, nursery foremen and farmers' calls to visit a site and collect samples when symptoms of physiological interruption or malformation appear. In some cases, a correctly sampled and carefully preserved tree part was sent to the pathology lab for analysis. The samples collected or received were brought to the lab, recorded and

processed to identify the causal organism of the plant distress. From the results of the lab analysis the information was entered in Microsoft Excel files and later exported into a MYSQL database for web hosting and control of access to the different target user groups i.e. university students, foresters, extension officers, scientists and farmers. The information files were then used to create the knowledge base of the KEFRI IPM DSS. Upon typing a query in the system, a user will be able to access certain information pertaining to symptoms, control and management of a disease.

For the pilot phase the database development team focussed on diseases affecting the common plantation species namely Eucalyptus, pines, cypress, *Grevillea robusta* for the high potential areas and *Melia volkensii* which is best suited for dry areas. Pathogens of trees from the review were described, records of their occurrence highlighted as well as management and control measures provided where known.

In the development of the KEFRI IPM DSS, the following modules were used:

1. Online Public Access Catalog (OPAC): This is the front page that all the users have access to. On this page one can traverse the application to any other page and module. The page also contains the query criterion which allows users to use the symptoms, tree species name and the location from which the data was collected to build a query. This helps a stakeholder scan through the database and view the disease details. The details can also be viewed as a PDF document and are downloadable as well.
2. Pests and Diseases Module: This module allows authorized system users to manage pests and diseases data. Under this module authorized users are able to enter, edit or delete pests and diseases data.
3. System Module: This module allows authorized users to change the application settings and set other control information that affects the flow of data and links

to various pages that make up the application.

4. GIS Module: This module controls the location of data collection points. It gives the user the exact locations of places where the disease data was collected on the Google Map.

Results and discussion

The review revealed that the KEFRI Pathology section had 3000 records of diseases from nurseries, plantations, wood lots, sawmills and natural forests. All the records were entered into Microsoft Excel sheets from the existing incident report cards and were being progressively uploaded onto the database. From the data entered, there were recurring pathogens across the tree species reported (Appendix 1). Key tree species affected were isolated and their range of diseases are listed and discussed below.

Key diseases of pine

Pines are exotic trees from Mexico introduced in Kenya for timber production. Before mid-1970s *Pinus radiata* was widely planted due to its superior wood quality. However, an epidemic of *Dothistroma* blight caused by the fungi *Dothistroma pini* caused a replacement of the species by *Pinus patula,* a more resistant species but of poorer wood quality (Senalik & Farber, 2021). At the nursery, seedlings can be infected by *Pythium sp.* which causes rotting of seeds in the seed bed before or shortly after germination, a condition known as damping off. The disease causes poor or no germination of seeds on the bed hence great losses in the nursery and in glasshouses. Control of the disease is through proper nursery hygiene with well aerated and optimal watering in the seed bed.

Another fungus which causes disease on pines is *Phytophthora sp.* The fungus causes slow growth of seedlings with chlorosis and wilting on foliage (Bose *et al*., 2019). In severe cases the pathogen causes root rot, dieback and death of seedlings. In plantations, *Phytophthora sp.* kills feeder roots and causes girdling lesions on larger roots or the root crown and collar rots and can also cause stem cankers in some tree species. However, it has been found that forest conditions do not favour this fungus' growth.

Botrytis cinerea causes blight on flowers, leaves and shoots of infected plants. It also causes fruit rots and sometimes cankers in succulent stems. Brown lesions are formed on leaves. This fungus reproduces indefinitely by colonizing dead and dying plant materials. It enters plants by direct penetration of leaves and succulent stems. It is dispersed by air and water in high humidity seasons and is also spread by insect vectors e. g fruit flies. It kills plant tissues by a combination of enzymatic and toxic actions, causes death of plants in green houses and in the field especially young plants.

Armillaria mellea causes rotting of roots that causes die back and wilting leading to death of trees. It forms white felty mycelium under bark of tree. Wood decay is confined to sapwood of killed roots and butt seen after the tree dies. It causes decomposition of roots and butts of dead trees and stumps. This fungus grows much more rapidly towards the tips of disease-girdled roots than butts of living trees (Coetzee *et al.*, 2005). It always works with insects and secondary pathogens to successfully colonize new plants. Due to its root-to-root contact mode of infection the fungus can cause death of trees and other plants in the infested area.

Dothistroma pini (Mycosphaerella pini) is a yellow turning reddish brown blight on pine needles affected by the disease. It causes stunted growth followed by shoot die back and eventual death of infected trees (Barnes et al., 2004). Needles turn brown as lesions start as spots and enlarge as bands and cause death of distal parts. Reddish colour is due to dothistromin, a toxin that kills the needles in advance of the fungus. Disease is dispersed by wind driven rain or mist. The fungus causes death of trees within five years of infection effectively killing young plantations and led to the stopping of *P. radiata* planting in Kenya in the late 1970s (Gibson, 1975).

Botryosphaeria ribis is an endophyte whose effect is mostly seen when the plant is stressed and kills rapidly by causing leaf blight, die-back and cankers on plants. Wood beneath cankers is brown and extends several centimeters below and above the canker (Chungu *et*

al., 2010). Diseased stems in gum producing plants have gummosis. The fungus has been reported to kill drought stressed pines. The pathogen belongs to a *B. dothidea* - *B. ribis* disease complex that causes severe problems to trees stressed by drought, freezing, wounds or insect attack. Infection is initiated by conidia dispersed by dripping or splashed water and can also be transmitted by pruning tools. The fungus causes fruit rots and death of plants and spreads very easily through plantations.

Diplodia pinea causes tip blight, resinous cankers on main stems and branches, dieback and misshapen tops, death of cones, seedling blight, gray to black stain on sapwood, stunted growth of young plantations and sometimes death of entire trees. When severe shoots are blighted, branches are deformed. Damage is usually severe to pines that are stressed by water shortage, heat, soil compaction or frost (Ivory, 1994). Damage to non-pine conifers occurs when there is environmental stress and a large supply of spores from pines. Pathogen overwinters in dead needles, stems, and cones dispersed when temperature and moisture permit. It enters needles through stomata and their spread occurs during warm wet weather.

Fusarium circinatum causes pitch canker-resin-soaked lesions on twigs and small branches. Eventual girdling occurs. Dieback is prominent on some species. When in seeds, the diseased seedlings wilt and die. This fungus is dispersed by air, water and insects. It is also transported with pine seeds. Lesion formation starts soon as the infection occurs and kills highly susceptible species by causing death of branches and deformation of trees, suppression of growth and death of seed crops (Sinclair & Lyon,2005).

Key diseases of *Eucalyptus* species in Kenya

Eucalyptus tree species are exotic species from Australia. Different species are suited to different agro-ecological zones in Kenya. *E. camaldulensis* is suited to semi-arid zones, *E. globulus* to high altitude areas (can tolerate frost), *E. saligna* to highlands and is prone to termite damage. Propagation of *Eucalyptus* species is by seedlings or

clones and direct sowing at site. Seeds do not require any pre-treatment. The species coppices well and has a wide range of uses including heavy and light construction (as timber), poles, posts, veneer, fuel wood and wind break.

Pythium sp. causes rotting of seeds before germination (pre-emergence damping off) leading to poor or no germination of seeds on the seed bed and watery stems and death of seedlings after germination (post emergence damping off). Soil borne fungi which favour high soil moisture content, high humidity, high seedling density and high organic content in the soil (Moorman, 2016).

Rhizoctonia solani causes leaf and shoot blight on seedlings. Seedlings develop water-soaked lesions, wilt and then die. The fungus grows as a saprophyte on soil and compost. It is also present in non-sterile soil and its growth is favoured by over watering and shade causing excessive moisture (Mutitu *et al*., 2008).

Erysiphe cichoracearum usually recorded as *Oidium* spp. is detected as powdery mildew on leaves of seedlings formed by a wide mat of mycelium on the leaves (Old *et al*., 2003) The fungus is dispersed by wind or water and germinates on the surfaces of leaves creating germ tubes and haustoria that help them get nutrients from the host. They survive as cleistothecia and start new infections when conditions are favorable, causes poor growth, necrosis and leaf fall thereby photosynthesis.

Botryosphaeria cankers causes shoot die back and stem cankers on trees in the field. It also causes kino exudation, forms lesions that can lead to bark cracking, eventual rot of sapwood and death of the tree (Slippers *et al*., 2009). This fungus has been classified as an opportunistic fungus that attacks the tree on the onset of stress and can be preceded by insect attack or poor pruning that exposes cambium to infection (Slippers & Wingfield, 2007). Clones are more susceptible to the pathogen.

Cryphonectria cankers cause basal cankers, branch stubs, girdling of stems and sudden death during hot weather. Wood decay below cankers is yellow-orange. Infection is mostly through wounds, natural growth cracks and branch stubs or exposed roots but can

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also be infected into new coppices from the old stump. Development of shallow network of cracks on bottom bark of the tree can lead to secondary infection by other fungi. Fungus growth is favoured by high rainfall, humidity and high temperatures and available susceptible hosts and grows more rapidly during dry seasons (Roux *et al*., 2005).

Mycosphaerella blight causes leaf spots, leaf blotch and leaf crinkles, necrosis around leaf margins, premature defoliation and stunting of trees (Carniege *et al*., 2007). Fungus growth is favoured by prolonged rainfall periods and abundant moisture during which the spores are released from fruiting bodies and spread to neighbouring susceptible hosts. Pseudothecia also form in cankers (Crous, 2002).

Stereum hirsutum is a wood decaying fungus that causes loss in mechanical strength of the wood. It causes white mottled rot of sapwood and heartwood (Gezahgne *et al*., 2003). Basidiocarps have smooth undersurface and bleed red fluids when injured. It forms sporophores on dead stumps and branches. Basidiospores from sporophores disseminate to form mycelium. Once inside, rhizomorphs spread intercellularly causing dry heart rot. It enters through wounds and branch stubs (Gibson, 1966).

Cylindrocladium spp. cause severe foliar and shoot blight by merging of tiny necrotic spores on leaf surface seen as leaf spots. Other symptoms of infection include; cutting, root and collar rots, damping off in very humid regions, twig dieback, wilting and death (Jimu *et al*., 2015). Fungi are resistant to bio-degradation hence they survive in soil as microsclerotia which germinate when stimulated by root exudates. Fungus growth is favored by high rainfall and high humidity as conidia are dispersed by water (Sharma & Mohanan, 1992). Attack is most notable in saplings and pole-sized trees as these are in a stage of growing rapidly. The fungus causes crown dieback and defoliation and leads to secondary infection by canker fungi which causes death of trees (Rodas *et al.,* 2005).

Botrytis cinerea causes blight on flowers leaves and shoots of infected plants. It also causes fruit rots and sometimes

cankers in succulent stems. Brown lesions are formed on leaves. This fungus reproduces indefinitely by colonizing dead and dying plant materials (Mwangi, 2014). It enters plants by direct penetration of leaves and succulent stems. It is dispersed by air and water in high humidity seasons and is also spread by insect vectors e.g fruit flies. It kills plant tissues by a combination of enzymatic and toxic actions and causes death of plants (especially young plants) in green houses and in the field.

Armillaria root rot causes growth reduction, yellowish leaves, branch die-back, rapid browning and death of the plant resin or gum production. Wood decay is confined to sapwood of killed roots and butt seen after the tree dies (Mwangi *et al*., 1994). The fungus causes decomposition of roots and butts of dead trees and stumps. Species of this fungus grows much more rapidly towards the tips of disease-girdled roots than butts of living trees and always works with insects and secondary pathogens to successfully colonize new plants. It causes death of trees and other plants around it.

Phytophthora root rot causes stunted leaves, bark cracks, necrotic lesions, basal cankers, collar and root rots, girdling of stems and gummosis (Bose *et al*., 2019). The fungus grows during high temperature seasons and germination occurs during wet seasons. It attacks from tiny roots followed by the large ones causing girdling and eventually death of large trees but its effects are more rapid on seedlings. It causes death of seedlings in the nursery and glass house and death of large trees in the field.

Key diseases of Cypress in Kenya

Cypress canker

A canker is a localized necrosis of the bark and cambium on stems, branches or twigs. They are often sunken because the stem continues to get bigger on the fringes of the infected parts. Also, callus may be produced around the canker that makes it more sunken. It is caused by several species of fungi. In Kenya, the disease was first observed in 1942 on *C. macrocarpa* and research found that *C. macrocarpa* was the most susceptible of the species he tested. The disease was later reported on *C. lusitanica* at Chehe in

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1947 and the pathology, spread and possible origin of the disease was studied by Rudd Jones (Rudd, 1953). By 1969 studies showed that the incidence of canker caused by *Lepteutypa cupressi* (*Monochaetia unicornis* Cooke & Ellis) had declined. In Kenya, plantations of *Cupressus macrocarpa* another exotic species were severely damaged by *Lepteutypa cupressi* (*Syn Seiridium unicorne* Cooke & Ellis; B. Sutton) a stem canker fungus (Odera & Arap Sang, 1980). The pathogen survives in infected bark tissue. During wet weather, spores are released and spread to nearby hosts or healthy branches. These spores are spread by splashing and water runoff. They can also be carried longer distances by contaminated pruning tools and movement of infected plants. Since the fruiting bodies needed for identification are found near oozing cankers, it is important to include the entire branch when sampling.

The disease causes cankers, branch deformation, branch and twig dieback. The first symptom of the disease is the production of resin. As the pathogen progresses it interferes with the sap-conducting system, eventually causing death of the branch or main trunk above the wound. Branches die rapidly, yellowing almost overnight as the foliage is starved of sap. Sunken cankers, with a reddish tinge, form at the entry point of the fungus, and resin often exudes from the edges of the cankers or through cracks in the bark. Individual cankers are long and thin and may be numerous along a branch. Spore-producing structures of the fungus can be seen on the bark surface as small, circular, black dots. They can also be transferred from plant to plant on pruning tools, or through the transport of infected cuttings or plants (Olembo, 1969).

Pestalotiopsis funerea causes damping off, root and collar rot of seedlings, needle blight, shoot or tip blight, twig die-back and stem cankers on affected plants. The fungus is both endophytic and pathogenic to pines which means that it attacks on the onset of stress and kills living tissue rapidly. The spores of the fungus are dispersed by splashing or running water and produce fruiting bodies under the epidermis of leaves,

stems, fruit and other flower parts. The conidia push up when the plant part is moistened. It causes many plant diseases which eventually kill the plant. It can be managed by avoidance of stress on the trees by planting the right species in the correct sites (Sinclair & Lyon, 2015).

Armillaria root rot

In tropical Africa, Armillaria root rot is prevalent in Central and Eastern Africa. Armillaria root rot has been reported on *Cupressus lusitanica* in the highlands of eastern Africa specifically in high-altitude areas of Kenya. The disease attacks the roots forming whitish area between the bark and the wood. It can also spread upwards to the stem. Armillaria root rot is caused by several species of the fungus *Armillaria*. However, *A. heimii* is by far the major causal species on *Cupressus lusitanica*. This can easily be grown on artificial media (Mwangi *et al*., 1994).

The production of resin at the collar is a common response of Abietaceae, especially pines, attacked by *A. ostoyae* or *A. heimii*. Infection of a root system does not immediately result in the appearance of symptoms on the aerial part. These only begin to show when the collar is attacked or when several large roots are destroyed (Coetzee *et al*., 2005). Attacked trees appear brownish which progress until the tree dies. The main symptom is the presence at the level of the cambium of white, thick, mycelial fans, sometimes constituting a continuous mycelial tube. Clusters of mushrooms form at the base of the infected tree, indicating attack. Fruit bodies though rare occur in clusters at the base of infected stumps and dead trees especially on *C. lusitanica*. Most of the fruit bodies that were found seem to correspond to the species *A. heimii* although they vary in size and some are often larger than those described by for *A. heimii*. Trees can die in patches as the fungus spreads through root-to-root contact.

Conclusion

Disease diagnosis is the first step in efficient control and management of pathogen spread to prevent outbreaks that cause yield losses. The work summarized here will be packaged in a software application that will help students, researchers and farmers to identify diseases affecting trees easily. It

has been deemed cost effective and with the right user education, has a huge potential to help curb tree diseases on species of commercial importance in Kenya. Several steps are yet to be taken to complete the KEFRI IPM DSS before it is ready for use and all suggestions will help improve the application.

Recommendations

All researchers are called upon to help improve the information in the database by reviewing the records in the query system. Use of compendia and decision support systems can help in faster disease identification which will in turn help reduce spread of the pests. It will also be an important tool for promotion of citizen science for data collection in forest pathology in Kenya and its neighboring countries.

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Appendix I: Summary table of key diseases of tree species in Kenya as per KEFRI pathology records

HOST NAME	***DISEASE NAME***	***SYMPTOMS***
Acacia mearnsii	*Armillaria mellea, Lenzites sp.*	No symptoms
Acacia melanoxylon	*Armillaria mellea Trametes hirsuta*	Rot
Acacia mollissima	*Lygia sp.*	Witches broom
Acacia podalyriifolia	*Sclerotium rolfsii*	Root rot
Acacia polycantha	*Armillaria mellea*	Root rot
Acrocarpus fraxinifolius	*Psathyrella disseminata*	Fungus fructification
Alnus nepalensis	*Alternaria tenuis*	Death of seedlings
Araucaria angustifolia	*Armillaria mellea*	Swollen with lots of resin, cracks and white mycelium
Arundinaria alpina	*Engleromyces geotzii*	Fructification
Cassia siamea	*Fusarium sp.*	Canker and extended Dieback
Cassipourea elliottii	*Hormodendron*	Superficial and internal stain
Cherry tree (culture)	*Armillaria mellea*	Diseased cherry tree
Chlorophora excelsa	*Cercospora sp., Helicobasidium purpureum, Oidium sp.*	Leaf infection, root rot, mildew infection

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Cupressus benthamii	*Polystictus versicolor*	white rot
Cupressus lusitanica	*Monochaetia unicornis*	Browning and death of branchlets, cankers
Cupressus lusitanica	*Polyporus balsameus*	specimen of butt rot and heart rot
Cupressus macrocarpa	*Coniophora cerebella*	Brown cubical rot
Cupressus macrocarpa	*Polystictus coriolus*	Sporophores on rotted wood
Cupressus macrocarpa	*Polystictus versicolor*	Butt rot
Cupressus macrocarpa	*Tyromyces albidus*	Heart rot
Cupressus sp.	*Armillaria mellea*	No symptoms
Cupressus sp.	*Biatorella resinae*	No symptoms
Cupressus sp.	*Ganoderma applantum*	Bracket of fomes
Cupressus sp.	*Polyporus balsamus*	Heart rot
Cupressus sp.	*Polytictus versicolor*	Heart rot
Eucalyptus citriodora	*Fusarium sp.*	Damping off
Eucalyptus maculata	*Fusarium sp.*	Damping off
Eucalyptus maidenii	*Mycosphaerella moelleriana*	Leaf spot
Eucalyptus paniculata	*Stereum hirsutum*	No symptoms
Eucalyptus resinifera	*Armillaria mellea*	Root rot, Trees dying singly
Eucalyptus saligna	*Stereum hirstum*	Gummous canker

Euclaea laurifolia	*Cronartium gilgianum*	Leaf spot with prominent fungus growth
Fallen trunk	*Polystictus sp.*	White stringy rot
Ficoloha laurifolia	*Fomes fastuosus*	Rot in living tree
Fungus fructification	*Urneola sp.*	Fungus fructification
Grevillea grassland	*Lepiota procera*	No symptoms
Grevillea robusta	*Polyporus gilvus*	Rot and sporophore from old stump
Grevillea robusta	*Polystictus versicolor*	white rot
Gymnospora luteola	*Lenzites palisotii*	white rot
Hagenia abyssinica	*Polystictus versicolor*	Pieces of brackets
Juglans sp.	*Gleosporium sp.*	Dieback
Juniperus procera	*Fomes demidoffii*	Fructification from standing trees
Juniperus procera	*Ceratostoma juniperae*	A common gall of native cedar
Juniperus procera	*Daedalea juniperina*	Brown cubical rot
Juniperus procera	*Tyromyces albidus*	Tree rotted and invaded by borers
Juniperus sp	*Daedalea juniperina*	Brown cubical rot
Lenzites trabea	*Bracket fungus*	dark coloured bracketsof a polypolous fungus
Malus pumila	*Bacterium tumefasciens*	Root gall

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Mwitundu	*Stereum hirsutum*	Brackets on wood
Ocotea usambarensis	*Armillaria mellea*	Radial cracks, root rot
Ocotea usambarensis	*Fomes senex*	Butt rot and bracket
Olea capensis	*Polystictus cumeabarium*	Rotten timber
Olea capensis	*Stereum hirsutum*	Fallen timber
Olea chrysophylla	*Panus fulvus*	Fructification on stump
Olea welwitschii	*Polytictus versicolor*	Rot associated with fruit bodies
Parinari sp.	*Stereum sp.*	White rot with fruit body
Pines and cypress	*Armillaria mellea*	Butt rot
Pinus canariensis	*Armillaria mellea*	Rot
Pinus caribaea	*Diplodia pinea*	Needle cast
Pinus caribaea	*Cylindrocarpon radicicola*	Root disease
Pinus clausa	*Armillaria mellea*	Root rot
Pinus halepensis	*Thelephora sp.*	No symptoms
Pinus Leiophylla	*Armillaria mellea*	Root rot
Pinus occidentalis	*Armillaria mellea*	Root rot
Pinus occidentalis	*Arthrinium sp.*	Minute button like objects on the needles
Pinus patula	*Armillaria mellea*	Root rot

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Pinus patula	*Pestalotiopsis sp.*	Tip Dieback
Pinus patula	*Botrytis blight*	Fungus growth at collar
Pinus patula	*Fusarium species*	Dying off
Pinus patula	*Phoma sp.*	Death of seedlings
Pinus patula	*Suillus luteus*	Fructification
Pinus pinaster	*Armillaria mellea, Lycoperdon sp.*	No symptoms
Pinus pinea	*Fusarium sp.*	Damping off of seedlings.
Pinus radiata	*Alternaria sp., Armillaria mellea, Cladosporium sp., Fusarium sp., Diplodia pinea, Dothistroma pini,*	Tip Dieback
Pinus radiata	*Hypholoma fasciculare, Naemacyclus niveus Pestalotiopsis virgatula, Polyporus acularius, Pythium sp.*	Fungus fructification, damping off
Pinus radiata	*Rhizoctonia solani, Thelephora terrestris*	No symptoms
Pinus radiata & Cupressus macrocarpa	*Armillaria mellea*	Trees dying off
Pinus radiata & P. patula	*Armillaria mellea*	Root rot
Pinus radiata, patula & caribaea	*Armillaria mellea*	All dead wood had a black zone lines in the butt. Upper wood was stained

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		yellow and had insect larvae in tunnels under bark.
Pinus sp.	*Fusarium sp.*	Needle fall on leading shoots particularly buds
Pinus taeda	*Armillaria mellea*	Root rot
Piptadenia sp.	*Polyporaceae*	No symptoms
Podocarpus sp.	*Coniophora cerebella*	Rot
Podocarpus sp.	*Corynelia uberata*	Leaves covered with black sooty sport
Prunus serotina	*Armillaria mellea*	White mycelium under the bark
Pygeum africanum	*Armillaria mellea*	Butt rot
Pygeum africanum	*Oidium sp.*	Powdery mildew
Schinus molle	*Armillaria mellea*	Root rot
Tectona grandis	*Cephaleuros sp.*	Rusty brown spotting of leaves
Unidentified stump	*Armillaria mellea*	Root rot
Unidentified stump	*Ganoderma alvondii*	Fructification
Widdringtonia whyteii	*Armillaria mellea*	No symptoms
Widdringtonia whyteii	*Botrytis blight*	Tip Dieback